Methods¶

In this section we present an annotated bibliography of analytical methods available in CoRA. This list will be updated as new methods are developed, published and added to the CoRA environment.

SEX¶

Bass WM (2005)

Human Osteology: A laboratory and field manual, 5th edition. Missouri Archaeological Society, Columbia, MO.

Purpose: Sex determination from the skull.

Characteristics of the cranium and mandible at six non-metric features are described (male vs. female): supraorbital ridge (prominent vs. smooth), supraorbital margins (blunt vs. sharp), palate/dentition (large vs. small), mastoid processes (large vs. small), frontal sinuses (large vs. small), and chin shape (square vs. rounded).

Buikstra JE, Ubelaker DH (1994)

Standards for Data Collection from Human Skeletal Remains. Arkansas Archeological Survey Research Series No. 44, Fayetteville, AR.

Purpose: Discussion of sexually dimorphic morphology of the skull and os coxae and the association with male and female.

CRANIAL MORPHOLOGY

Features of the cranium and mandible are scored from minimal expression ("1") to maximal expression ("5").

Nuchal crest : View the lateral profile of the occipital and compare it with the diagram. Feel the surface of the occipital with your hand and note any surface rugosity, ignoring the contour of the underlying bone. Focus upon the rugosity attendant to attachment of nuchal musculature. In the case of minimal expression, the external surface of the occipital is smooth with no bony projections visible when the lateral profile is viewed. Maximal expression defines a massive nuchal crest that projects a considerable distance from the bone and forms a well-defined bony ledge or "hook."

Mastoid process: Score this feature by comparing its size with that of the surrounding structures such as the external auditory meatus and the zygomatic process of the temporal bone. The most important variable to consider in scoring this trait is the volume of the mastoid process, not its length. Minimal expression is a very small mastoid process that projects only a small distance below the inferior margins of the external auditory meatus and the digastric groove. A massive mastoid process with lengths and widths several times that of the external auditory meatus would be considered maximal expression.

Supraorbital margin: Begin by holding your finger against the margin of the orbit at the lateral aspect of the supraorbital foramen. Then hold the edge of orbit between your fingers to determine its thickness. Look at each of the diagrams to determine which it seems

to match most closely. In an example minimal expression, the border should feel extremely sharp, like the edge of a slightly dulled knife. A thick, rounded margin with a curvature approximating a pencil should be scored as maximal expression.

Glabella: Viewing the cranium from the side. Minimal expression is characterized by minimal prominence of the glabella/supraorbital ridges with the contour of the frontal being smooth and little to no projection at the midline. Maximal expression involves a massive glabellar prominence, forming a rounded, loaf-shaped projection that is frequently associated with well-developed supraorbital ridges.

Mental eminence: Hold the mandible between the thumbs and index fingers with thumbs on either side of the mental eminence. Move the thumbs medially until the delimit the lateral borders of the mental eminence. In examples of minimal expression, there is little or no projection of the mental eminence above the surrounding bone. By contrast, massive expression is one in which the mental eminence occupies most of the anterior portion of the mandible.

OS COXAE MORPHOLOGY

See Phenice (1969) for morphology/scoring of the ventral arc, subpubic concavity, and ischiopubic ramus.

Greater sciatic notch: This feature tends to be broad in females and narrow in males. The shape of the greater sciatic notch is not as reliable as the subpubic region. For scoring this feature, it is best to use the diagrams provided in the original publication to find

the closest match. The broadest notch is scored as "1", while the narrowest is scored as "5".

Preauricular sulcus: The preauricular sulcus appears more often in females than males, with four positive expressions (score of 1-4) and the lack of expression (score of "0"). The scores are as follows: 0 = absence of preauricular sulcus; 1 = the preauricular sulcus is wide; 2 = the preauricular sulcus is wide (usually greater than 0.5 cm) but shallow; 3 = the preauricular sulcus is well defined but narrow, less than 0.5 cm deep; 4 = the preauricular sulcus is a narrow (less than 0.5 cm), shallow, and smooth-walled depression.

OVERALL ASSESSMENT

Based on an overall assessment of all sexually dimorphic features of the os coxae and skull, separately, an individual can be assigned:

0 = undetermined sex. Insufficient data are available for sex determination

1 = female. There is little doubt that the structures represent a female.

2 = probable female. The structures are more likely female than male.

3 = ambiguous sex. Sexually diagnostic features are ambiguous.

4 = probable male. The structures are most likely male than female.

5 = male. There is little doubt that the structures represent a male.

Phenice TW (1969)

A newly developed visual method of sexing the os pubis. American Journal of Physical Anthropology 30:297-301.

Purpose: Sex estimation based on three features of the adult os coxa: the ventral arc, subpubic concavity, and the ischiopubic ramus.

Sample: Terry Skeletal Collection, Smithsonian Institution; n = 275; Black and White males (n = 20 and 160, respectively) and females (n = 52 and 43, respectively).

Each feature is determined to be: 1) female, 2) ambiguous, or 3) male.

Ventral arc: Slightly elevated ridge extending inferiorly from pubic crest across the ventral surface to the lateral most extension of the subpubic concavity. Present in females.

Subpubic concavity: A lateral recurve of the ischio-pubic ramus below the lower margin of the pubic symphysis. Present in females.

Ischiopubic ramus: Portion extending from the inferior pubic symphysis to the ischial tuberosity. The ramus is broad and generally flat in males, while a narrower ramus with a ridge is typical of female morphology.

The ischiopubic ramus is most likely to display ambiguous morphology, and the ventral arc is least likely to display ambiguous morphology.

If sex assessment is based on one or two of the features that are definitely male or female (ventral

arc and subpubic concavity), the estimate will be correct at least 96% of the time.

Rogers TL (1999)

A visual method of determining the sex of skeletal remains using the distal humerus. Journal of Forensic Sciences 44:57-60.

Purpose: Sex estimation based on the characteristics of four dimorphic features of the distal humerus: trochlear constriction, trochlear asymmetry, olecranon fossa shape and depth, and the angle of the medial epicondyle. These are "scored" as male or female based on their morphology.

Sample: Developed on the Grant Skeletal Collection, University of Toronto (20th century anatomy series), n = 202 (175 males, 27 females); tested on known individuals from the University of New Mexico Documented Collection (n = 35; 28 males, 7 females) and the William M. Bass Donated Skeletal Collection (n = 93; 74 males, 19 females).

Trochlear constriction: constricted and spool-shaped in females; less constricted in males.

Trochlear symmetry: asymmetrical in females; symmetrical in males.

Olecranon fossa shape and depth: deep oval in females; shallow triangle in males. Shape is more important than depth.

Angle of the medial epicondyle: distinctly raised in females; flat or slightly raised in males.

In ambiguous cases (two traits scored as male, two traits scored as female), greater weight should be given to the olecranon fossa.

The greatest accuracy is achieved when all four features are present and scorable.

Rogers NL, Flournoy LE, McCormick WF (2000)¶

The rhomboid fossa of the clavicle as a sex and age estimator. Journal of Forensic Sciences 45:61-67.

Purpose: Sex estimation based on clavicle morphology, specifically, the presence or absence of the rhomboid fossa, which is a pitted or depressed marking on the inferior sternal end of the clavicle.

Sample: William F. McCormick Skeletal Collection, University of Tennessee - Knoxville; n = 344; 113 females, 231 males; White (n=301), Black (n=38), "Other" non-White (n=5); Ages: 10-92 years.

Males are more likely than females to have a rhomboid fossa, and rhomboid fossae are more commonly exhibited in younger individuals than older individuals.

Posterior probabilities (left clavicle): fossa present, P(male) = 92.2%, P(female) = 7.8%; fossa absent, P(male) = 41.4%, P(female) = 58.6%

Posterior probabilities (right clavicle): fossa present, P(male) = 81.7%, P(female) = 18.3%; fossa absent, P(male) = 41.0%, P(female) = 59.0%

Authors suggest these posterior probabilities cannot be used on other populations, but due to the

preponderance of fossae on male clavicles, the presence of a fossa likely indicates a male individual.

Walker PL (2005)¶

Greater sciatic notch morphology: Sex, age, and population differences. American Journal of Physical Anthropology 127:385-391.

Purpose: Provides empirical probabilities of being male or female for a given sciatic notch score, following Buikstra and Ubelaker (1994).

Sample: Americans from the Hamann-Todd Collection, Cleveland Museum of Natural History and Terry Skeletal Collection, Smithsonian Institution (n = 211; 114 males, 97 females); and Europeans from the St. Bride's Collection, St. Bride's Church in London (n = 85; 51 males, 34 females).

A score of 1 typically indicates a female, while a score of 3 or greater usually indicates a male. A score of 2 represents intermediate morphology, although a larger percentage of males than females exhibit this degree of expression.

Probability of being male for each score: 1 - 0.12; 2 - 0.66; 3 - 0.88; 4 - 0.93; 5 - 0.90.

Probability of being female for each score: 1 - 0.88; 2 - 0.34; 3- 0.12; 4 - 0.07; 5 - 0.10

There is also a relationship between age-at-death and sciatic notch score, with younger people tending to have wider greater sciatic notches.

Walker PL (2008)¶

Sexing skulls using discriminant function analysis of visually assessed traits. American Journal of Physical Anthropology 136:39-50.

Purpose: Provides empirical probabilities of being male for a given score of observed cranial morphology following the ordinal scales presented in Buikstra and Ubelaker (1994).

Sample: Americans from the Hamann-Todd Collection, Cleveland Museum of Natural History and Terry Skeletal Collection, Smithsonian Institution and Europeans from the St. Bride's Collection, St. Bride's Church in London (n = 304; 164 males, 140 females). In addition, archaeological specimens (7000 B.P. to European contact) from the Santa Barbara Museum of Natural History and the Department of Anthropology, University of California, Santa Barbara were utilized (n = 156).

The sectioning point is 0, and scores less than 0 are more likely to be male, and scores greater than 0 are more likely to be female.

The probability of being male for each trait for a given score is provided.

Discriminant function equations are also provided, utilizing the scores of two to three characteristics.

AGE

**JJJJ

Berg GE (2008)

Pubic bone age estimation in adult women. Journal of Forensic Sciences 53:569-577.

Purpose: Age estimation for older females, re-defining the Suchey-Brooks phases V and VI, and adding phase VII.

Sample: n = 189 females; Balkan (n = 85) and William M. Bass Donated (WBD) Skeletal Collection (n = 104)

The calculated mean and standard deviations for the WBD sample are listed below and can be applied to an American female population.

Phase IV: 35.5 ± 3.8 yrs

Phase V: 49.7 ± 5.8 yrs

Phase VI: 64.2 ± 9.0 yrs

Phase VII: 74.2 ± 10.9 yrs

Blankenship JA, Mincer HH, Anderson KM, Woods MA, Burton EL (2007)

Third molar development in the estimation of chronologic age in American Blacks as compared with Whites. Journal of Forensic Sciences 52:428-433.

Purpose: Age estimation of African American populations by scoring third molar development radiographically using the Demirjian et al. stages (A-H).

Sample: n = 637 African Americans and n = 563 American Whites, between 14.0 and 24.9 years, from across the United States and Canada. The American White sample was obtained from a previous study.

Black–White differences were significant with developmental stages occurring in Blacks a year or so earlier than Whites.

The empirical likelihood that an African American male with fully developed M3's is at least 18 years old is 93% and that for African American female is 84%. Corresponding risks for Whites are 90% and 93%, respectively.

Brooks S, Suchey JM (1990)

Skeletal age determination based upon the os pubis: A comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods. Human Evolution 5:227-238.

Purpose: The Suchey-Brooks system is a 6-phase system (I-VI) for age estimation for males and females that utilizes the morphology of the entire symphyseal surface following the six phase system for males described by Katz and Suchey (1986).

Sample: n = 1,225, males and females, of known ages at death from the Los Angeles Medical Examiner’s Office.

Phase Descriptions and Ages (mean ± 1 SD, 95% range)

Phase I: Symphyseal face has a billowing surface (ridges and furrows) which usually extends to include the pubic tubercle. The horizontal ridges are well-marked and ventral beveling may be commencing. Although ossific nodules may occur on the upper extremity, a a key to the recognition of this phase is the lack of delimitation of either upper or lower

extremity. Females: 19.4 ± 2.6 yrs (15-24 yrs); Males: 18.5 ± 2.1 yrs (15-23 yrs).

Phase II: The symphyseal face may still show ridge development. The face has commencing delimitation of lower and/or upper extremities occurring with or without ossific nodules. The ventral rampart may be in beginning phases as an extension of the bony activity at either or both extremities. Females: 25.0 ± 4.9 yrs (19-40 yrs); Males: 23.4 ± 3.6 yrs (19-34 yrs).

Phase III: Symphyseal face shows lower extremity and ventral rampart in process of completion. There can be a continuation of fusing ossific nodules forming the upper extremity and along the ventral border. Symphyseal face is smooth or can continue to show distinct ridges. Dorsal plateau is complete. Absence of lipping of symphyseal dorsal margin; no bony ligamentous outgrowths. Females: 30.7 ± 8.1 yrs (21-53); Males: 28.7 ± 6.5 yrs (21-46 yrs).

Phase IV: Symphyseal face is generally fine grained although remnants of the old ridge and furrow system may still remain. Usually the oval outline is complete at this stage, but a hiatus can occur in upper ventral rim. Pubic tubercle is fully separated from the symphyseal face by definition of upper extremity. The symphyseal face may have a distinct rim. Ventrally, bony ligamentous outgrowths may occur on inferior portion of pubic bone adjacent to symphyseal face. If any lipping occurs it will be slight and located on the dorsal border. Females: 38.2 ± 10.9 yrs (26-70 yrs); Males: 35.2 ± 9.4 yrs (23-57 yrs).

Phase V: Symphyseal face is completely rimmed with some slight depression of the face itself, relative to

the rim. Moderate lipping is usually found on the dorsal border with more prominent ligamentous outgrowths on the ventral border. There is little or no rim erosion. Breakdown may occur on superior ventral border. Females: 48.1 ± 14.6 yrs (25-83 yrs); Males: 45.6 ± 10.4 yrs (27-66 yrs).

Phase VI: Symphyseal face may show ongoing depression as rim erodes. Ventral ligamentous attachments are marked. In many individuals the pubic tubercle appears as a separate bony knob. The face may be pitted or porous, giving an appearance of disfigurement with the ongoing process of erratic ossification. Crenulations may occur. The shape of the face is often irregular at this stage. Females: 60.0 ±12.4 yrs (42-87 yrs); Males: 61.2 ± 12.2 yrs (34-86 yrs).

Buckberry JL, Chamberlain AT (2002)

Age estimation from the auricular surface of the ilium: Arevised method. American Journal of Physical Anthropology 119:231-239.

Purpose: A composite scoring method for age estimation from the auricular surface. This method is a revision of the existing auricular surface aging method by Lovejoy et al (1985), and scores independent components of the auricular surface, rather than the gestalt.

Sample: n = 180 known-age individuals from Christ Church, Spitalfields, London were utilized for the blind test of the new method.

Features examined (scores): transverse organizaiton (1-5), surface texture (1-5), microporosity (1-3),

macroporosity (1-3), and apical changes (1-3). After each feature is examined and scored, a composite score is generated.

This revised method yields scores that have a higher correlation with age than the Suchey-Brooks pubic symphysis system for this sample.

No significant differences were seen between sexes or sides; therefore, the same method and age estimates can be applied to both sexes.

Stages (Composite Score) and Ages (mean ± 1 SD)

Stage I (5-6): 17.33 ± 1.53 yrs (16-19 yrs)

Stage II (7-8): 29.33 ± 6.71 yrs (21-38 yrs)

Stage III (9-10): 37.86 ± 13.08 yrs (16-65 yrs)

Stage IV (11-12): 51.41 ± 14.47 yrs (29-81 yrs)

Stage V (13-14): 59.94 ± 12.95 yrs (29-88 yrs)

Stage VI (15-16): 66.71 ± 11.88 yrs (39-91 yrs)

Stage VII (17-19): 72.25 ± 12.73 yrs (53-92 yrs)

İşcan MY, Loth SR, Wright RK (1984)

Age estimation from the rib by phase analysis: White males. Journal of Forensic Sciences 29:1094-1104.

Purpose: Age estimation based on the morphology of the sternal end of the fourth rib (White Males).

Sample: n = 118 White males of known age at death from the Broward County Medical Examiner's Office, Florida.

This system is a 9-phase system (0-8), requiring the sternal end of the 4th rib be compared to three-dimensional casts of known age exemplars.

Phase Descriptions and Ages (mean ± 1 SD, 95% range)

Phase 0: The articular surface is flat or billowy with a regular rim and rounded edges. The bone itself is smooth, firm, and very solid.

Phase 1: There is a beginning amorphous indentation in the articular surface, but billowing may also still be present. The rim is rounded and regular. In some cases scallops may start to appear at the edges. The bone is still firm, smooth and solid. Mean age = 17.3 ± 0.50 yrs (16.5-18.0 yrs).

Phase 2: The pit is now deeper and has assumed a V-shaped appearance formed by the anterior and posterior walls. The walls are thick and smooth with a scalloped or slightly wavy rim with rounded edges. The bone is firm and solid. Mean age = 21.9 ± 2.13 yrs (20.8-23.1 yrs).

Phase 3: The deepening pit has taken on a narrow to moderately U-shape. Walls are still fairly thick with rounded edges. Some scalloping may still be present but the rim is becoming more irregular. The bone is still quite firm and solid. Mean age = 25.9 ± 3.50 yrs (24.1-27.7 yrs).

Phase 4: Pit depth is increasing, but the shape is still a narrow to moderately wide U. The walls are thinner, but the edges remain rounded. The rim is more irregular with no uniform scalloping pattern remaining. There is some decrease in teh weight and

firmness of the bone, however, the overall quality of the bone is still good. Mean age = 28.2 ± 3.83 yrs (25.7-30.6 yrs).

Phase 5: There is little change in pit depth, but the shape in this phase is predominantly a moderately wide U. Walls show further thinning and the edges are becoming sharp. Irregularity is increasing in the rim. Scalloping pattern is completely gone and has been replaced with irregular bony projections. The condition of the bone is fairly good, however, there are some signs of deterioration with evidence of porosity and loss of density. Mean age = 38.8 ± 7.00 yrs (34.4-42.3 yrs).

Phase 6: The pit is noticeably deep with a wide U-shape. The walls are thin with sharp edges. The rim is irregular and exhibits some rather long bony projections that are frequently more pronounced at the superior and inferior borders. The bone is noticeably lighter in weight, thinner, and more porous, especially inside the pit. Mean age = 50.0 ± 11.17 yrs (44.3-55.7 yrs).

Phase 7: The pit is deep with a wide to very wide U-shape. The walls are thin and fragile with sharp, irregular edges and bony projections. The bone is light in weight and brittle with significant deterioration in quality and obvious porosity. Mean age = 59.2 ± 9.52 yrs (54.3-64.1 yrs).

Phase 8: In this final phase the pit is very deep and widely U-shaped. In some cases the floor of the pit is absent or filled with bony projections. The walls are extremely thin, fragile, and brittle with sharp, highly irregular edges and bony projections. The bone is

very lightweight, thin, brittle, friable, and porous. "Window" formation is sometimes seen in the walls. Mean age = 71.5 ± 10.27 yrs (65.0-78.0 yrs).

İşcan MY, Loth SR, Wright RK (1985)

Age estimation from the rib by phase analysis: White females. Journal of Forensic Sciences 30:853-863.

Purpose: Age estimation based on themorphology of the sternal end of the fourth rib (White Females).

Sample: The reference population consists of 86 White females of known age at death.

This system is a 9-phase system (0-8), requiring the sternal end of the 4th rib be compared to three-dimensional casts of known age exemplars.

Phase Descriptions and Ages (mean ± 1 SD, 95% range)

Phase O: The articular surface is nearly flat with ridges or billowing. The outer surface of the sternal extremity of the rib is bordered by what appears to be an overlay of bone. The rim is regular with rounded edges, and the bone itself is firm, smooth, and very solid.

Phase 1: A beginning, amorphous indentation can be seen in the articular surface. Ridges or billowing may still be present. The rim is rounded and regular with a little waviness in some cases. The bone is still solid, firm, and smooth. Mean age = 14.0 (no SD or CI provided).

Phase 2: The pit is considerably deeper and has assumed a V-shape between the thick, smooth anterior and posterior walls. Some ridges or billowing may still remain inside the pit. The rim is wavy with some scallops beginning to form at the rounded edge. The bone itself is firm and solid. Mean age = 17.4 ± 1.52 yrs (15.5-19.3 yrs).

Phase 3: There is only slight if any increase in pit depth, but the V-shape is wider, sometimes approaching a narrow U as the walls become a bit thinner. The still rounded edges now show a pronounced, regular scalloping pattern. At this stage, the anterior or posterior walls or both may first start to exhibit a central, semicircular arc of bone. The rib is firm and solid. Mean age = 22.6 ± 1.67 yrs (20.5-24.7 yrs).

Phase 4: There is a noticeable increase in the depth of the pit, which now has a wide V- or narrow U-shape with, at times, flared edges. The walls are thinner but the rim remains rounded. Some scalloping is still present, along with the central arc; however, the scallops are not as well defined and the edges look somewhat worn down. The quality of the bone is fairly good but there is some decrease in density and firmness. Mean age = 27.7 ± 4.62 yrs (24.4-31.0 yrs).

Phase 5: The depth of the pit stays about the same, but the thinning walls are flaring into a wider V- or U-shape. In most cases, a smooth, hard, plaque-like deposit lines at least part of the pit. No regular scalloping pattern remains and the edge is beginning to sharpen. The rim is becoming more irregular, but the central arc is still the most prominent projection. The bone is noticeably lighter in weight, density and

firmness. The texture is somewhat brittle. Mean age = 40.0 ± 12.22 yrs (33.7-46.3 yrs).

Phase 6: An increase in pit depth is again noted, and its V- or U-shape has widened again because of pronounced flaring at the end. The plaque-like deposit may still appear but is rougher and more porous. The walls are quite thin with sharp edges and an irregular rim. The central arc is less obvious and, in many cases, sharp points project from the rim of the sternal extremity. The bone itself is fairly thin and brittle with some signs of deterioration. Mean age = 50.7 ± 14.93 yrs (43.3-58.1 yrs).

Phase 7: In this phase, the depth of the predominantly flared U-shaped pit not only shows no increase, but actually decreases slightly .Irregular bony growths are often seen extruding from the interior of the pit. The central arc is still present in most cases but is now accompanied by pointed projections, often at the superior and inferior borders, yet may be evidenced anywhere around the rim. The very thin walls have irregular rims with sharp edges. The bone is very light, thin, brittle, and fragile, with deterioration most noticeable inside the pit. Mean age = 65.2 ± 11.24 yrs (59.2-71.2 yrs).

Phase 8: The floor of the U-shaped pit in this final phase is relatively shallow, badly deteriorated, or completely eroded. Sometimes it is filled with bony growths. The central arc is barely recognizable. The extremely thin, fragile walls have highly irregular rims with very sharp edges, and often fairly long projections of bone at the inferior and superior borders. "Window" formation sometimes occurs in the

walls. The bone itself is in poor condition - extremely thin, light in weight, brittle, and fragile. Mean age = 76.4 ± 8.83 yrs (70.4-82.3 yrs).

Kasper KA, Austin D, Kvanli AH, Rios TR, Senn DR (2009)

Reliability of third molar development for age estimation in a Texas Hispanic population: A comparison study. Journal of Forensic Sciences 54:651-657.

Purpose: Age estimation of Hispanic populations by scoring third molar development radiographically using the method of Demirjian et al. (1973) for crown and root formation.

Sample: Hispanic individuals (n = 950) aged from 12-22 years

The third molar of the Hispanic sample was found to develop 8-18 months faster than American Caucasians as reported by Mincer et al. (1993).

Prediction intervals (95% confidence) for each stage and sex

Maxilla

Stage B: Females 10-21 yrs; Males 8-19 yrs

Stage C: Females 12-18 yrs; Males 12-17 yrs

Stage D: Females 11-19 yrs; Males 12-18 yrs

Stage E: Females 12-20 yrs; Males 12-18 yrs

Stage F: Females 13-20 yrs; Males 13-19 yrs

Stage G: Females 14-21 yrs; Males 14-20 yrs

Stage H: Females >15 yrs, with a 78.8% probability of being at least 18 years; Males >15 yrs, with a 71.4-74.7% probability of being at least 18 years

Mandible

Stage B: Females 11-20 yrs; Males 8-20 yrs

Stage C: Females 12-18 yrs; Males 12-17 yrs

Stage D: Females 11-19 yrs; Males 11-18 yrs

Stage E: Females 13-19 yrs; Males 13-18 yrs

Stage F: Females 14-21 yrs; Males 13-20 yrs

Stage G: Females 14-22 yrs; Males 15-21 yrs

Stage H: Females >16 yrs, with a 87.1-89.8% probability of being at least 18 years; Males >16 yrs, with a 85.8-86.4% probability of being at least 18 years

Additional Reference: Demirjian A, Goldstein H, Tanner JM (1973). A new system of dental age assessment. Human Biology, 45(2):211-227.

Langley-Shirley N, Jantz RL (2010)¶

A Bayesian approach to age estimation in modern Americans from the clavicle. Journal of Forensic Sciences 55:571-583.

Purpose: Age estimation based on a 3-phase or 5-phase system for medial clavicular fusion for modern American individuals.

Sample: n = 1289 (1044 male, 245 female): 594 individuals (448 male, 146 female) between 11 and 33 years from the William F. McCormick Clavicle Collection, 354 individuals (255 male, 99 female) between 11 and 30 years from the Hamann-Todd Osteological Collection), and 341 males between 16 and 33 years from the Korean War.

Due to secular trends, observed ages for each phase are provided separately for each sample. This information can be used to produce age ranges based on the mean and standard deviations using the most appropriate sample population.

A Bayesian approach is also utilized to provide age ranges based on the highest posterior density of the McCormick sample for use with more modern cases. This provides a more conservative, statistically sound estimate that is less sensitive to outliers. These age ranges are provided below.

Age ranges (95% CI) for each system and sex

5-phase system

1: Females ≤16.2 yrs; Males ≤17.4 yrs

2: Females 13.5-21.0 yrs; Males 14.4-23.0 yrs

3: Females 16.7-25.7 yrs; Males 17.9-27.5 yrs

4: Females 19.9-29.3 yrs; Males 20.5-30.6 yrs

5: Females ≥22.5 yrs; Males ≥24.1 yrs

3-phase system

1: Females ≤16.5 yrs; Males ≤17.4 yrs

2: Females 14.1-27.1 yrs; Males 14.9-28.5 yrs

3: Females ≥22.1 yrs; Males ≥24.0 yrs

Lovejoy CO, Meindl RS, Pryzbeck TR, Mensforth RP (1985)¶

Chronological metamorphosis of the auricular surface of the ilium: A new method for determination of adult skeletal age at death. American Journal of Physical Anthropology 68:15-28.

Purpose: An 8-phase age estimation system based on auricular surface morphology, considering changes to the granularity and density, macroporosity, billowing, striae, apex, retroauricular area, and transverse organization.

Sample: The Todd Collection (n = 500), the Libben Collection (n = 250), and forensic cases from the Cuyahoga County Coroner's Office, Ohio (n = 14).

Two completely blind tests were conducted to assess the accuracy and bias of the new method utilizing different individuals from the Todd Collection (n = 98 and 108, respectively).

There are five basic phases in which the auricular surfaces progresses: early post-epiphyseal phase, young adult phase, mid adult phase, early senescent phase, and breakdown.

Eight age modes are developed based on the progression of auricular surface morphology through the basic five phases. The age ranges are provided below, with the most relevant characteristics. See reference for a more detailed description for each mode.

Age Ranges and their Relevant Characteristics

20-24: billowing and very fine granularity.

25-29: reduction of billowing, but retention of youthful appearance.

30-34: general loss of billowing, replacement by striae, and distinct coarsening of granularity.

35-39: uniform coarse granularity.

40-44: transition from coarse granularity to dense surface; this may take part over islands of the surface of one or both faces.

45-49: completion of densification with complete loss of granularity.

50-59: dense irregular surface of rugged topography and moderate to marked activity in periauricular areas.

60+: breakdown with marginal lipping, macroporosity, increased irregularity, and marked activity in periauricular areas.

Mann RW, Jantz RL, Bass WM, Willey PS (1991)

Maxillary suture obliteration: A visual method for estimating skeletal age. Journal of Forensic Sciences 36:781-791.

Purpose: Age estimation by assessing suture closure of the four maxillary (palatal) sutures.

Sample: 186 skeletons of known age, sex, and race from three skeletal collections (Louisiana State University, University of Tennessee, and the Terry Skeletal Collection, Smithsonian Institution): 46 White

males, 32 White females, 64 Black males, and 44 Black females.

Males exhibit more suture obliteration than females at the same age.

Although this method cannot be used for exact estimates of individual age, it is valuable in establishing an estimated age range or minimum age.

First Evidence of Partial Obliteration (by suture)

Incisive: 16 yrs

Transverse palatine: 22 yrs

Posterior median palatine: 25 yrs

Anterior median palatine: 27 yrs

Earliest Complete Obliteration (by suture and sex)

Incisive: Females 20 yrs; Males 20 yrs

Transverse palatine: Females 27 yrs; Males 26 yrs

Posterior median palatine: Females 84 yrs; Males 33 yrs

Anterior median palatine: Females 67 yrs; Males 40 yrs

McKern TW, Stewart TD (1957)

Skeletal Age Changes in Young American Males. Quartermaster Research and Development Command Technical Report EP-45, Natick, MA.

Purpose: Age estimation by scoring epiphyseal union of various skeletal elements, as well as morphology of the pubic symphysis.

Sample: American males who died as a result of the Korean War from 1950 to 1952.

Because this sample is represented by military males, individuals below 17 years of age are not present, and these methods are most applicable for American males who died prior to (ca.) 1960.

Epiphyseal union: The stage of epiphyseal union is scored on a scale of 0 to 4 (0 - unfused, 1 - beginning fusion, 2 - largely fused, 3 - fused, 4 - fused with no remnant fusion line). The stage of epiphyseal fusion can then be compared to the published standards. McKern and Stewart present only raw data in tabular form.

Pubic symphysis: The McKern-Stewart system is a 3-component system that scores the dorsal and ventral demifaces and the rim of the pubic symphysis (each component having a 0-5 stage of development). Morphology can be compared to a cast set comprised of a representative pubic symphysis for a score of 1 to 5 for each component. The scores for each component are combined and correspond to a given age range.

Meindl RS, Lovejoy CO (1985)¶

Ectocranial Suture Closure: a revised method for the determination of skeletal age at death based on the lateral-anterior sutures. American Journal of Physical Anthropology 68:57-66.

Purpose: Age estimation by scoring (0-open, 1-minimal closure, 2-significant closure, 3-complete obliteration) ectocranial vault and lateral anterior suture closure at ten sites.

Sample: Hamann-Todd Collection, Cleveland Museum of Natural History (n = 236).

Scores are combined to produce two composite scores that correspond to estimates of age-at-death, which were found to be independent of race and sex.

Mincer HH, Harris EF, Berryman HE (1993)¶

The A.B.F.O. study of third molar development and its use as an estimator of chronological age. Journal of Forensic Sciences 38:379-390.

Purpose: Age estimation for American Whites and Blacks by scoring third molar development radiographically using the eight-grade classification system by Demirjian et al. (1973).

Sample: n = 823, males (46%) and females (54%) between the ages of 14 and 24 years from across the United States and Canada. The sample consisted of white (80%), Black (19%), and “other” (1%).

Although the third molar is the most variable tooth, the formation of the third molar can be useful for age estimation when other elements are unavailable.

Mean ages (± 1 SD) at attainment of stages for third molar formation

Maxilla

Stage D: White Females 16.0 ± 1.55 yrs; White Males 16.0 ± 1.97 yrs; Blacks nd

Stage E: White Females 16.9 ± 1.85 yrs; White Males 16.6 ± 2.38 yrs; Blacks nd

Stage F: White Females 18.0 ± 1.95 yrs; White Males 17.7 ± 2.28 yrs; Blacks nd

Stage G: White Females 18.8 ± 2.27 yrs; White Males 18.2 ± 1.91 yrs; Blacks 19.3 ± 3.37 yrs

Stage H: White Females 20.6 ± 2.09 yrs; White Males 20.2 ± 2.09 yrs; Blacks 20.4 ± 3.14 yrs

Mandible

Stage D: White Females 16.0 ± 1.64 yrs; White Males 15.5 ± 1.59 yrs; Blacks nd

Stage E: White Females 16.9 ± 1.75 yrs; White Males 17.3 ± 2.47 yrs; Blacks nd

Stage F: White Females 17.7 ± 1.80 yrs; White Males 17.5 ± 2.14 yrs; Blacks 17.2 ± 3.14 yrs

Stage G: White Females 19.1 ± 2.18 yrs; White Males 18.3 ± 1.93 yrs; Blacks 18.5 ± 2.68 yrs

Stage H: White Females 20.9 ± 2.01 yrs; White Males 20.5 ± 1.97 yrs; Blacks 21.4 ± 2.34 yrs

If an individual has reached Stage H, then one can be reasonably confident that the individuals is at least 18 years of age. An upper age limit should not be imposed.

Nawrocki SP (1998)¶

Regression formulae for the estimation of age from cranial suture closure. In Forensic Osteology: Advances in the Identification of Human Remains, 2nd ed., edited by Kathy Reichs, pp. 293-317. Charles C. Thomas, Springfield, IL.

Purpose: Age estimation by scoring ectocranial, endocranial, and maxillary suture closure.

Sample: American White (n = 49) and Black (n = 51) males and females (n = 50 for each).

Twenty-seven cranial landmarks are scored, including 16 from the ectocranial surface, 7 from the endocranial surface, and 4 from the palate, on a scale of 0 to 3.

Ten of the ectocranial landmarks are the same as Meindl and Lovejoy's (1973) landmarks.

Scores can be summed and utilized in a regression equation to predict age.

Eight equations for predicting age from all cranial suture landmarks are provided.

Because incomplete crania are often recovered, additional formulae using only landmarks of the calotte are also provided (Equations 9 – 15).

Osborne DL, Simmons TL, Nawrocki SP (2004)¶

Reconsidering the auricular surface as an indicator of age at death. Journal of Forensic Sciences 49:905-911.

Purpose: Age estimation based on auricular surface morphology.

Sample: n = 266; the Terry Skeletal Collection, Smithsonian Institution (n = 72), and the Bass Donated Collection, University of Tennessee (n = 194), which represent early 20th century and late 20th century individuals, respectively.

This method is a modified 6-phase system of the existing 8-phase auricular surface aging method by Lovejoy et al (1985).

Phase Descriptions and Ages (mean ± 1 SD, suggested age range)

Phase 1: Billowing with possible striae; mostly fine granularity with some coarse granularity possible. 21.1 ± 2.98 yrs (≤27 yrs)

Phase 2: Striae; coarse granularity with residual fine granularity; retroauricular activity may be present. 29.5 ± 8.20 yrs (≤46 yrs)

Phase 3: Decreased striae with transverse organization; coarse granularity; retroauricular activity present; beginnings of apical change. 42.0 ± 13.74 yrs (≤69yrs)

Phase 4: Remnants of transverse organization; coarse granularity becoming replaced by densification; retroauricular activity present; apical change; macroporosity is present. 47.8 ± 13.95 yrs (20-75 yrs)

Phase 5: Surface becomes irregular; surface texture is largely dense; moderate retroauricular activity;

moderate apical change; macroporosity. 53.1 ± 14.14 yrs (24-82 yrs)

Phase 6: Irregular surface; densification accompanied by subchondral destruction; severe retroauricular activity; severe apical change; macroporosity. 58.9 ± 15.24 yrs (29-89 yrs)

Rougé-Maillart C, Vielle B, Jousset N, Chappard D, Telmon N and Cunha E (2009)¶

Estimation of skeletal age at death in adults using the acetabulum and the auricular surface on a Portuguese population. Forensic science international 188(1-3), pp.91-95.

Purpose: A composite scoring method for age estimation from a combination of the auricular surface and acetabulum.

Sample: 462 hip bones from a series of identified skeletons, of known age and sex, from the Coimbra Identified Skeletal Collection (Portugal)

Features examined in the auricular surface (scores): transverse organization (1-7), surface texture (1-5), porosity (1-5), and apical activity (1-3).

Features examined in the acetabulum (scores): rim (1-5), fossa (1-4), and apical activity posterior cornus (1-3).

After each feature is examined and scored, a composite score is generated.

Score Category (Composite Score): Age range (probability)

Score Category I (7-10): 15-24 yrs (81.6%), 15-34 yrs (100%)

Score Category II (11-14): 25-34 yrs (65%), 15-44 yrs (100%)

Score Category III (15-18): 35-44 yrs (52.7%), 25-44 yrs (95.5%)

Score Category IV (19-22): 45-54 yrs (43.5%), 35-64 yrs (87.9%)

Score Category V (23-26): 55-64 yrs (42.4%), 45-74 yrs (85%)

Score Category VI (27-30): 75-85 yrs (40.6%), >65 yrs (92.1%)

Score Category VII (31-32): >84 yrs (60.5%), >75 yrs (86.9%)

Samworth R, Gowland R (2007)

Estimation of adult skeletal age-at-death: Statistical assumptions and applications. International Journal of Osteoarchaeology 17:174-188.

Purpose: Age estimation based on features of the os coxa.

Sample: 18th-century English and 20th-century Portuguese.

Age ranges for developmental stages throughout the skeleton are provided.

This method is meant for aging the adolescent skeleton.

This method provides 90% prediction intervals for each combination of pubic symphysis (scored following the Suchey-Brooks method, n = 376) and auricular surface (scored following the Lovejoy method, n = 448).

These prediction intervals have been found to be accurate for 20th-century Americans as well (Passalacqua 2010).

When both scores can be observed on the same individual, a combined age estimate may be produced in this manner.

Such a combined age estimate may be more precise than the pubic symphysis alone, particularly for individuals whose pubic symphyses are in phases 3-6.

Prediction intervals (90%) by pubic symphysis (PS) and auricular surface (AS) scores

PS 1: AS 1 13.3-29.7 yrs; AS 2 16.3-36.3 yrs; AS 3 18.8-42.3 yrs; AS 4 20.6-46.7 yrs; AS 5 21.6-48.8 yrs

PS 2: AS 1 15.5-34.6 yrs; AS 2 18.5-41.0 yrs; AS 3 21.0-46.9 yrs; AS 4 23.0-51.5 yrs; AS 5 24.3-54.3 yrs

PS 3: AS 1 18.1-40.5 yrs; AS 2 21.0-46.6 yrs; AS 3 23.5-52.2 yrs; AS 4 25.7-57.0 yrs; AS 5 27.2-60.5 yrs; AS 6 28.0-62.4 yrs

PS 4: AS 1 20.9-47.6 yrs; AS 2 23.7-53.0 yrs; AS 3 26.3-58.3 yrs; AS 4 28.5-63.2 yrs; AS 5 30.5-67.5 yrs; AS 6 31.9-70.8 yrs; AS 7 32.8-73.3 yrs

PS 5: AS 1 24.1-56.2 yrs; AS 2 26.8-60.4 yrs; AS 3 29.3-65.1 yrs; AS 4 31.7-70.2 yrs; AS 5 34.0-75.4 yrs;

AS 6 36.4-80.5 yrs; AS 7 38.6-85.6 yrs; AS 8 40.7-90.8 yrs

PS 6: AS 1 27.7-66.6 yrs; AS 2 30.1-69.0 yrs; AS 3 32.5-72.9 yrs; AS 4 35.1-78.1 yrs; AS 5 38.0-84.4 yrs; AS 6 41.4-91.8 yrs; AS 7 45.2-100.5 yrs; AS 8 49.6-111.2 yrs

Schaefer M, Black S, Scheuer L (2009)¶

Juvenile Osteology: A Laboratory and Field Manual. Academic Press, Burlington, MA.

Purpose: Age estimation based on epiphyseal fusion.

Age ranges for developmental stages throughout the skeleton are provided.

This method is meant for aging the juvenile skeleton.

This manual is a compilation of aging data from numerous sources from the last hundred years from a variety of journals and texts.

Schaefer MC (2008)¶

A summary of epiphyseal union timings in Bosnian males. International Journal of Osteoarchaeology, 18:536-545.

Purpose: Age estimation based on epiphyseal fusion.

Sample: Bosnian males who died as a result of the fall of Srebenica, aged 14 to 30 years old

Epiphyseal fusion: The stage of epiphyseal union is scored on a scale of 0 to 2 (0 - unfused, 1 - fusion in progress, 2 - fusion complete). The stage of

epiphyseal fusion can then be compared to the published standards.

Age ranges for developmental stages throughout the skeleton are provided.

This method is meant for aging the adolescent skeleton.

ANCESTRY¶

Edgar HJH (2013)¶

Estimation of ancestry using dental morphological characteristics. Journal of Forensic Sciences, 58:S3-S8.

Purpose: Ancestry estimation using nonmetric morphological dental traits to distinguish European American, African American, and Hispanic American individuals.

Sample: 509 individuals of Hispanic, African and European ancestry.

The dental traits and scoring definitions are derived from The ASU dental series (see Turner et al. 1991).

Additional Reference: Turner CG II, Nichol CR, Scott GR. (1991). Scoring procedures for key morphological traits of the permanent dentition: the Arizona State University dental anthropology system. In: Advances in Dental Anthropology, Kelley M, Larsen CS (eds) Wiley-Liss, New York, NY.

Gill GW (1998)¶

Craniofacial Criteria in the Skeletal Attribution of Race. In Forensic Osteology: Advances in the

Identification of Human Remains, 2nd ed., Reichs K (ed), pp.293-317. Charles C. Thomas, Springfield, IL.

Purpose: Ancestry estimation based on nonmetric craniofacial morphology.

These data represent a mid-1990s collective assessment of observers' experiences in the field.

The variation of twenty-two traits of the skull are compared and described as typical features of American Indian, Black, East Asian, Polynesian, and White populations.

The authors state that while all of the presented traits can be useful for ancestry estimation, those of the nose and mouth have shown to be the most useful.

The user should be cautious when applying this method as little attention is provided to the underlying distribution of traits among the populations surveyed.

Method should be deprecated.

Hefner J (2009)¶

Cranial nonmetric variation and estimating ancestry. Journal of Forensic Sciences, 54:985-995.

Purpose: Provides underlying frequency distributions by ancestry for 11 commonly used cranial nonmetric traits.

Sample: n = 747 from four skeletal collections, comprised of prehistoric and contemporary individuals, which are separated into an African, Asian, European, and Native American.

Ten of the 11 traits examined had frequency distributions with significant differences ($p < 0.001$) between groups, but the range in variation of these traits, particularly within groups, suggests that ancestry estimation cannot be conducted by visual observation alone.

Hefner J, Ousley SD (2014)¶

Statistical classification methods for estimating ancestry using morphoscopic traits. Journal of Forensic Sciences, 59:883-890.

Purpose: Ancestry estimation using six cranial nonmetric traits to separate American Whites and Blacks.

OSSA is a nonparametric method that compresses morphological variation into two classes.

To employ OSSA, all six non-metric traits are scored using the original character states (original ordinal categories, 0-4), and then compressed to the corresponding dichotomous state (0,1).

All six OSSA scores (0-6) are summed.

Values of four or greater are classified as American White; values of three or less are classified as American Black.

Rhine S (1990)¶

Non-metric skull racing. In Skeletal Attribution of Race: Methods for Forensic Anthropology, edited by

G. W. Gill and S. Rhine, pp. 9-20. Maxwell Museum Anthropological Papers No. 4, Albuquerque, NM.

Purpose: Ancestry estimation based on cranial morphology (Asian, Black, White).

Forty-five cranial and dental traits commonly used by Mountain, Desert, and Coastal Forensic Anthropologists were assessed for distinguishing between “American Caucasoid,” “Southwestern Mongoloid,” and “American Black:” 18 from the braincase, 13 from the face, 7 dental, and 7 from the mandible.

The traits determined to be the most useful in ancestry assessment are provided for each group.

ZONES¶

Knusel CJ, Outram AK (2004)¶

Fragmentation: The zonation method applied to fragmented human remains from archaeological and forensic contexts. Environmental Archaeology, 9:85-98.

Purpose: Presents a standardized representation of zones on the human skeletal elements to allow for comparisons and analysis of an entire assemblage.

Anatomical descriptions and zone drawings are provided.

MEASUREMENTS¶

Buikstra JE, Ubelaker DH (1994)¶

Standards for Data Collection from Human Skeletal Remains. Arkansas Archeological Survey Research Series No. 44, Fayetteville, AR.

Purpose: Data collection standardization from skeletal remains. This source consolidates multiple non-metric methods and measurements into a single source.

Byrd JE, Adams BJ (2003)¶

Osteometric sorting of commingled human remains. Journal of Forensic Sciences 48(4):717–724.

Byrd JE (2008)¶

Models and methods for osteometric sorting. In: Recovery, Analysis, and Identification of Commingled Human Remains, edited by B. J. Adams and J. E. Byrd, pp. 199–220. Humana Press, New Jersey.

Byrd and Adams (2015)¶

Updated measurements for osteometric sorting. DPAA CIL document, dated 16 December 2015.

Dwight T (1905)¶

The size of the articular surfaces of the long bones as characteristic of sex; an anthropological study. American Journal of anatomy 4:19-32.

Holland TD (1992)¶

Estimation of adult stature from fragmentary tibias. Journal of Forensic Sciences 37:1223–1229.

Holland TD (1995)¶

Estimation of adult stature from the calcaneus and talus. American Journal of Physical Anthropology 96:315–320.

Howells WW (1973)¶

Cranial Variation in Man: A Study by Multivariate Analysis of Patterns of Difference among Recent Human Population. Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University, Volume 67, Cambridge, MA.

Hrdlicka A (1920)¶

Anthropometry. American Journal of Physical Anthropology 3:147-173.

Langley NR, Jantz LM, Ousley SD, Jantz RL, Milner GS (2016)¶
Data collection procedures for forensic skeletal material 2.0. University of Tennessee and Lincoln Memorial University: Tennessee. http://fac.utk.edu/wp-content/uploads/2016/03/DCP20_webversion.pdf

Martin R (1957)¶
Lehrbuch der Anthropologie. Dritte Aufl.

Martin R, Knussmann R (1988)¶
Anthropologie: handbuch der vergleichenden biologie des menschen. Stuttgart: Gustav Fischer.

Montagu MFA (1960)¶
A Handbook of Anthropometry. Charles C. Thomas, Springfield, Illinois.

Moore-Jansen PM, Ousley SD, Jantz RJ (1994)¶

Data Collection Procedures for Forensic Skeletal Material. 3rd ed. Department of Anthropology Report of Investigations No. 48. University of Tennessee, Knoxville, TN.

Seidemann RM, Stojanowski CM, Doran GH (1998)¶

The use of the supero-inferior femoral neck diameter as a sex assessor. American Journal of Physical Anthropology 107:305-313.

Simmons T, Jantz RL, Bass WM (1990)¶

Stature estimation from fragmentary femora: A revision of the Steele method. Journal of Forensic Sciences 35:628–636.